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Robinson F. Ramirez

A LABORATORY ABRADER FOR TESTING WARP YARNS

AND EVALUATING SIZING COMPOUNDS

A THESIS

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Master of Science in Mechanical Engineering

By

Robinson Pito Ramirez

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A LABORATORY ABRADER FOR TESTING WARP YARNS

AND EVALUATING SIZING COMPOUNDS

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A LABORATORY ABRADER FOR TESTING WARP YARNS AND EVALUATING SIZING COMPOUNDS

Robinson P. Ramirez

ABSTRACT

How does a manufacturer of sizing determine the adequacy of a sizing formula without undertaking the full-scale, time consuming process of actually testing it on a weaving loom? Some devices and techniques have been developed for testing the potentialities of a given untried formula with or without the use of a weaving loom. These devices yield results which are based on relative amounts of shedding, on direct surface abrading and on direct tensioning or on some combination of these, employing one or several warp yarns per trial. Since these machines have a greater number of disadvantages than advantages, none have yet been adopted as a standard for testing the weaveability of a warp yarn or the effectiveness of a sizing compound.

In this paper, a new laboratory yarn abrader is introduced for the sole purpose of determining the effects of a size on warp yarns, rapidly and accurately. This machine has been designed and built to impart to the test yarns, as nearly as practicable, the abrasive and tensile

actions which a loom exerts on a warp yarn during the weaving operation.

Yarn samples were tested with the new abrader and with the K. Zweigle Abrader to compare the results. There was very good agreement between the results of the two machines although a sizable difference in the standard deviations existed.

CHAPTER I

INTRODUCTION

During the course of weaving operations in a textile mill, every loom has a number of unproductive periods or loom stoppages. Each stoppage occurs when a warp yarn or the filling breaks. Warp stoppages are more common than filling breaks and, thus, affect the productive capacity of a mill appreciably. Although, unfortunately, these expensive interruptions cannot be entirely eliminated they can be diminished to a great extent.

Castle and Dawson (1)* broadly classify the factors which affect the weaving properties of warps, into three main divisions: a. faulty construction, b. faulty maintenance and c. faulty yarn.

Faulty yarn can be made less faulty by greater care and improvement in the yarn making process (called spinning).

The spinning of cotton into yarns to be used in weaving is a very critical step in the manufacture of fabric materials. Such spinning imperfections as thin places, slubs, streaks and variable twists on the spun yarn have a substantial effect on its weaving qualities. There is such a great difference between spinning yarn and weav-

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*Numbers in parenthesis identify references listed in Bibliography.

ing it that a chasm virtually exists between the two. The property of spun yarn which attempts to link this chasm, is its ability to be woven efficiently. This particular ability is known in the textile circles as weaveability. It depends tremendously on the spinning of the yarn, on the slashing operation which the yarn undergoes and on other factors introduced by virtue of the characteristics of a weaving loom.

Faulty yarn can also be made more resistant to breakage during the sizing operation by employing better size mixtures. Slashing is the term used for this operation.

The main object of sizing warp yarns is to give them a surface film, first, to add strength to the main yarn so as to allow them to withstand adequately the stresses to which subjected during the weaving and second, to impart a protection against permanent damage from the loom abrasions. This is desired to derive efficient production of good quality woven fabric. As such, there are certain basic requirements of a good textile size to be used on spun cotton warp yarns. It should impart on sized yarn such qualities as:

1. Lubricity-- diminishes frictional effects.
2. Toughness-- increases its resistance to abrasion.

3. Strength-- increases its resistance to fluctuating stresses.
4. Flexibility-- increases its resistance to strain.
5. Preservability-- protects it from mildew.

A study by Brown (2) gave rise to a tabulation of the nature and incidence of warp breaks in percentage. The following is a breakdown of his results:

Warp breaks attributed to size, 24.7%

Warp breaks not attributed to size, 41.6%

Warp breaks attributed to unknown causes, 33.8%

He attributed to knots as much as 15 percent of the 33.8 percent listed above for unknown. It is agreed that if such a high percentage of breaks are due to knots, more attention should be placed on this cause. However, much of the remaining 18.8 percent could be attributed to the formula used whether directly or indirectly. Therefore, the possibility exists that as much as 24.7 plus 15 percent (which amounts to 39.7 percent) of all the breaks can be ascribed to sizing.

After two years of investigations, Brown (3) shows that the estimated loss in productive capacity of 200 automatic looms (from warp breaks only), amounts to about 750 yards of material, for a 45 hour week of operation. Considering that the present day mills operate anywhere from eight to twelve times this number of looms, the loss which is due to warp breaks alone would be about 7,500 yards per week. If about 39.7 percent of the warp breaks could be ascribed to sizing, as mentioned before, the production loss would be about 3,000 yards per week. In view of this, it is quite rational to infer that a perfect size is well worth developing.

The weaving efficiencies of looms are not as near the 100 percent mark as they could be if the weaveability of warp yarns were improved by employing better sizing compounds. It is unfortunate, though, that no standard method has been adopted for determining the weaveability of warp yarns or for adequately evaluating sizing formulas without undertaking fullscale tests utilizing weaving looms or model looms.

Castle and Dawson's (4) comments are:

> A very real snag in the development of new sizes is the problem of evaluation. Laboratory methods are useful, but at most they can serve only to eliminate actual obvious failures. The real test is in the loom. Here again the many variables that enter into a systematic assessment of loom efficiency complicate the evaluation of a trial sizing and are apt to act as a deterrent.

The Old Timer (5) makes the following remarks:

> Next, to get the best results for loom stoppage tests, it was necessary to place all the warps sized with sample sizing on a set of looms which, of course, involved considerable expense in taking off the regular warp in order to replace them with sample warps. All of this procedure took so much time and attention of someone, to be sure the test was conducted properly, that we were continually asking ourselves if there wasn't some practical method we could use which eliminated all or most of this time and expense.

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Bradbury (6) summarizes it in the following manner:

> In an investigation of the effect of warp sizes on the weaving behavior of continuous filament yarn, the direct method of a fullscale sizing and weaving trial is usually adopted. Whatever the advantages of this method, it has the serious drawbacks that it is expensive in material and time and it is unsuitable when the weaving possibilities of a large number of sizes have to be examined.

In the past, several techniques have been utilized at the weaving rooms to determine the effect of sizing. Probably the three most common methods are: 1) the weaver's opinions, 2) counting the number of loom stoppages which are due to warp breaks and 3) determining the loom efficiency. Experience from the use of these techniques has shown that both the weaver's opinions and the loom efficiency are not very reliable and are misleading because of the many variables involved. This is particularly true when the difference amongst compared warps is not very pronounced. Since counting of the number of warp breaks is very time consuming and because of the many inconsistencies encountered, this method is absolescent.

Presently, there are several machines and techniques which have been developed for evaluating sizing and the weaveability of a warp. Those which appear to be of any consequence are:

1. The Shed Tester
2. The Kendal Abrader
3. The Taber Yarn Abrader
4. The Abrasion Tester

5. The Old Timer Abrader
6. The Walker Abrader
7. The K. Zweigle Abrader

The Shed Tester (7) is basically a miniature loom without a shuttle and is used to make preliminary loom evaluations of size mixtures and sizing techniques. This is done by measuring the quantity of shed per unit weight of yarn tested per unit time.

The Kendall Tester (8) is also a miniature loom which has no shuttle action or beat-up motion. In this case, a carriage draws the yarn through the tester at a predetermined rate for a distance equivalent to the path of travel of the yarn in an actual weaving loom. This cycle is repeated until all of the ends being tested have broken. A record is made of the number of abrasive cycles required for each end and of the quantity of shed during the operations.

The Taber Abrader (9) is such that the yarn ends are wrapped around the cardboard disk which fits on a turntable. As the specimen rotates, the yarn is abraded partly along the yarn length and partly diagonally to the yarn.

In the Abrasion Tester (10), parallel ends of yarn are clamped on one end and passed over a glass rod at the opposite end where they are tied to equal weights to maintain a given constant tension. Immediately underneath the warp yarns, there is a wheel with spokes, each of which contains a friction blade at its end. As the wheel revolves about an axis perpendicular to the warp as well as in a plane parallel to it, each blade beats on the warp and imparts to it a certain amount of abrasive action.

The Old Timer Abrader (11) is essentially a small scale loom which uses small canvas bags with bird shot in them to maintain a desired tension.

The Walker Abrader (12) consists of a stationary cross-bar which holds each yarn as it hangs on individual weights. Each strand passes through a series of pins which are staggered and supported by a movable plate which oscillates in a plane parallel to the warp. The pins abrade the yarns by rubbing against them as the movable plate oscillates.

The K. Zweigle Abrader (13) is fully described in chapter two. It bases its results on the number of abrasion cycles required to break a given sample. The sample is subjected primarily to abrasion cycles from an oscillating cylinder. This cylinder has sandpaper wrapped around it to act as the abradant.

Some of these testers are claimed to yield a fairly accurate evaluation of textile sizes. From a study of their descriptions and some tabulated results it cannot be negated that, in general, they can be used to evaluate sizes with some degree of accuracy. Some of these machines have the disadvantage of requiring a considerable amount of time for one testing period. Others are of such a design nature that they do not emulate the stresses, strains and frictional (abrasive) forces which are characteristic of a weaving loom. However, results yielded by these machines are of a comparative character and probably serve their intended purposes.

It is obvious from the preceding discussion that there is a definite need for a standard accurate and rapid warp yarn tester.

One of the motives of this work is to introduce and describe a new rapid smallscale laboratory abrader for assessing the effectiveness of sizes on the weaveability of warp yarns. Into this machine were designed approximately the same essential features of a weaving loom. It simulates as nearly as practicable the stress, strain and frictional characteristics imparted a warp as it undergoes weaving in a loom. Hereafter, this tester will be called The Laboratory Abrader.

The Laboratory Abrader incorporates the following features:

1. Harness action without heddles
2. Beat-up motion without shuttle
3. Variable tension control.
4. Coordinated take-up and let-off controls which draw the yarn ends through the abrader intermittently for a predetermined distance during every pick cycle.

In preparing The Laboratory Abrader for testing, one continuous end of approximately twenty-four yards in length is wound on the abrader so that the equivalent of six test yarns are threaded and ready for testing. The ends are abraded until all of them have broken and the number of cycles which it took to break each yarn end is recorded.

The K. Zweigle Abrader was also used on yarns from the same samples for the purpose of comparison. No attempt was made to correlate the breakage frequencies with the weaveability of the yarns since the necessary mill information was unavailable. The results from this machine agreed quite well with those of the tests which were run on The Laboratory Abrader. A very pronounced scatter existed, however, in the Zweigle Abrader data. It showed a percentage standard deviation from the mean as high as 51.4 percent as compared to a high of 15.4 percent from the data of The Laboratory Abrader.

The values of the frictional and tensile forces which were designed into the new abrader were obtained from a thesis presented by Kennedy(14).

CHAPTER II

APPARATUS

The following textile testing devices were utilized in this work:

1. A Saxl Tension-meter
2. A K. Zweigle Abrader
3. The Laboratory Abrader
4. A Scott single strand stress-strain machine

In addition, miscellaneous equipment was utilized for the friction determination of various parts of The Laboratory Abrader.

The Saxl Tension-meter.--This is a mechanical device used for the purpose of determining the yarn tension during the test runs. The tensions in grams were read directly on the dial indicator of the mechanism.

The K. Zweigle Abrader.--This abrasion tester was manufactured by K. Zweigle of Reutlingen, Germany. Although this machine does not purport to emulate a loom in its abrading action, it has the advantage that it can test a sample of twenty ends of yarn fairly quickly.

The basic components of this machine are (see Fig. I): an abrasive cylinder, B; a back-board with nipples to attach samples to, A; a guide bar, C; a clamp to secure the ends, D; weights to maintain constant tension, E; a dial counter; and a fractional horsepower motor.

For operation, twenty ends of yarn are individually wound about a respective nipple (A), extended over the abrasive cylinder (B), passed over the guide bar (C), and tied to small weights (D). At (E), a clamp is swung into place to secure the yarns. The motor is started and the abrasive cylinder immediately under the ends of yarns begins to oscillate for a range of about three inches. This produces the desired rubbing effect on the underside of the yarn. Since the abradant (fine grain sandpaper of 500A roughness) is wrapped about the abrading cylinder, the yarns become abraded and fall by virtue of the constant pulling effect of the overhanging weights attached to each yarn. To maintain as fresh an abrading surface as possible, the oscillating cylinder rotates intermittently about its own axis, one revolution for every twenty cycles of abrading action.

The coarseness of the sandpaper that is used is selected to suit the size (counts) of yarn to be tested, i.e., heavier yarns require coarser grade paper, etc.

This machine can be run at sixty or eighty cycles per minute. The tests were actually performed at eighty cycles per minute.

<u>The Laboratory Abrader</u>.--In essence, this new apparatus consists of: take-up and let-off rolls, tension control eccentric, guide pins along the yarn path, harness action

pins, initial tension drums, tension-meter, and reed.

The following steps are taken to thread the machine (Refer to Fig. II): One end of a single yarn specimen of about twenty-four yards in length is temporarily clamped at a. The free end is now trained over and under the let-off rollers at b and passed over a guide 1 through the tension-meter c. The yarn continues over and under pins 2 and 3 respectively, under one harness action pin d and around guide pins e and 4. It returns to pass over the other harness action pin f, over guide pin g, to the take-up roller h, and finally to wrap around the initial tension drum a. Then, the remaining portion of the free end is trained repeatedly over the same path until six complete threading cycles have taken place. The loose end of the yarn is tied to the originally clamped end and the initial tension roll is pressed down several times to equalize the tension on the entire length of yarn. As each yarn is now equally taut, each of two spring clips with weights are clamped to the yarn at points A and B and the warp is cut at point C. The weights maintain a desired initial static tension as they hang on each extremity of the warp. The reed, consisting of five actual reed wires open at one end, is now located in place so that each dent carries three ends. The machine is finally ready for testing.

By referring to Figs. 2 through 5, the mechanism action can be followed fairly easily. Fig. 3 shows the

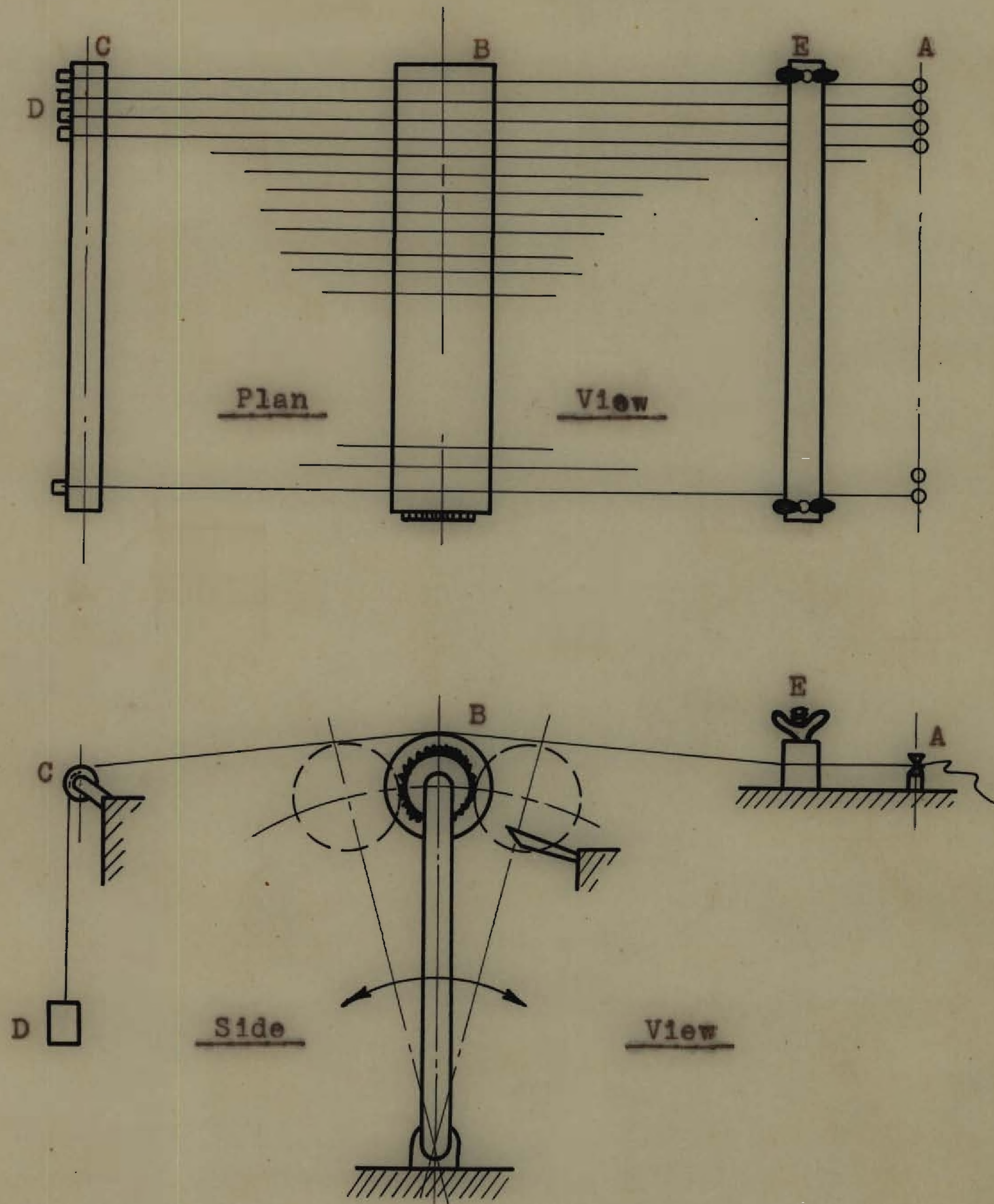

Fig. 1. Tw o Views of the K. Zweigle Abrader

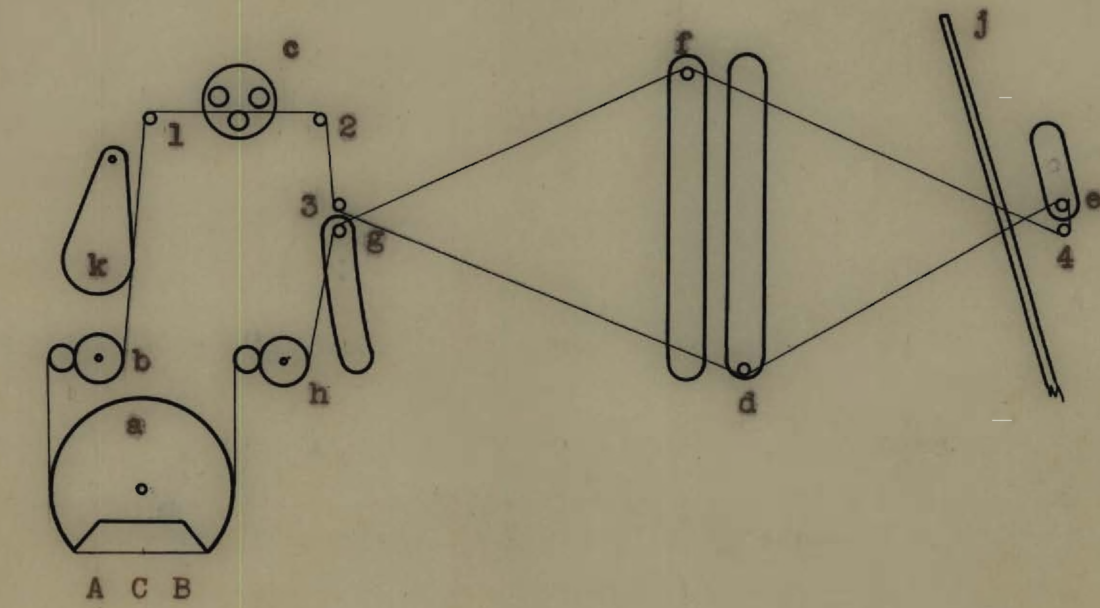

Fig. 2. Laboratory Abrader with Open Shed

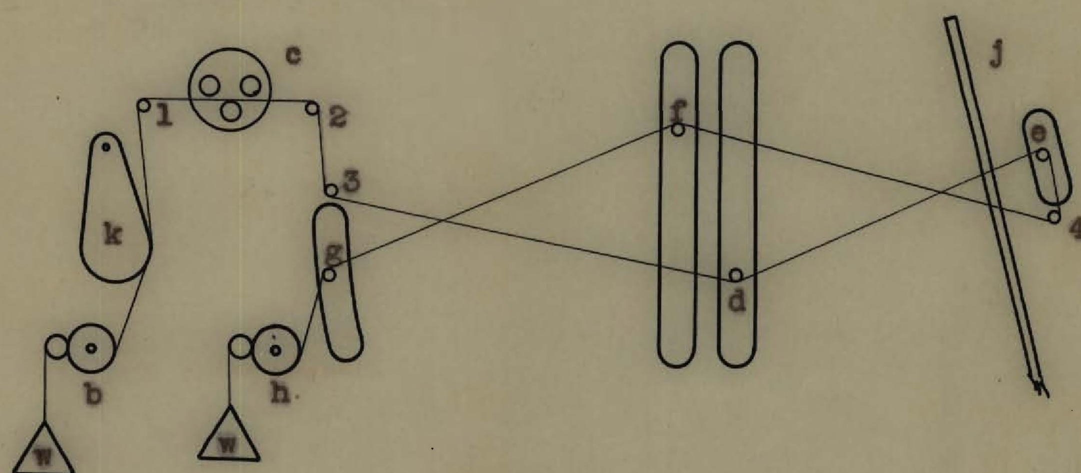

Fig. 3. Laboratory Abrader with Shed Partly Closed

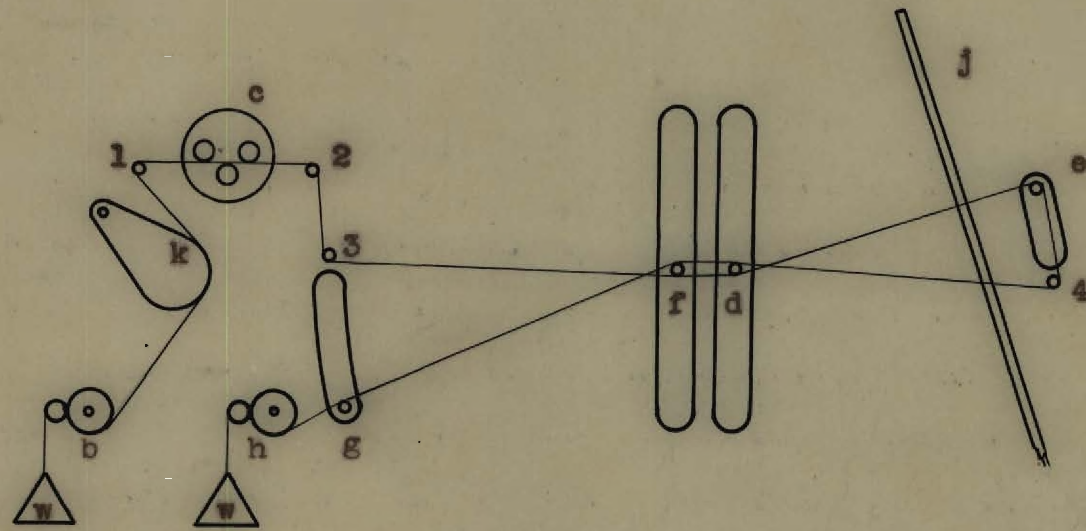

Fig. 4. Laboratory Abrader with Harnesses Level

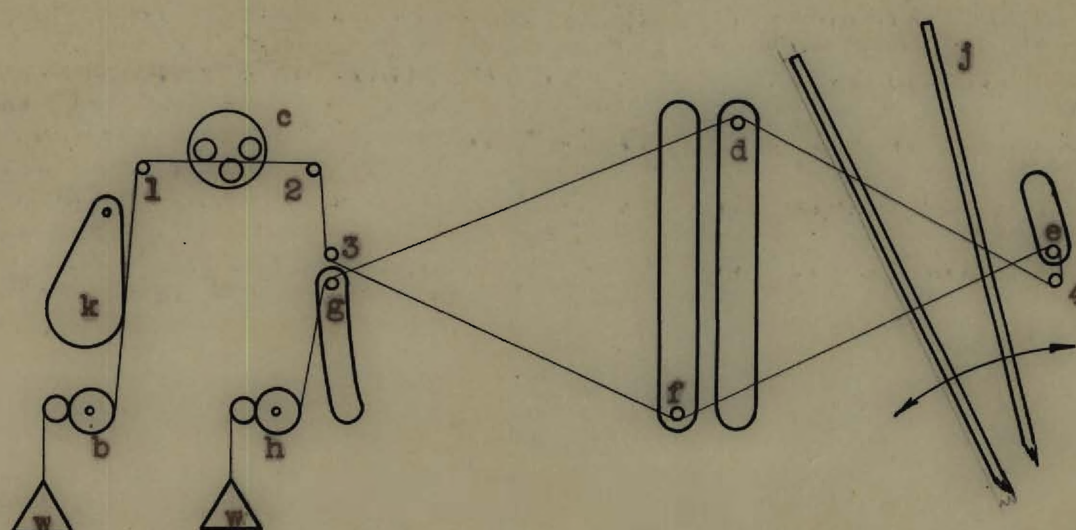

Fig. 5. Laboratory Abrader with Open Shed

harness pin f on its way down and pin d on its way up. Guide pins g and e begin to move down and up respectively and the eccentric k swings slightly counterclockwise to take up the slack. Fig. 4 shows the harness pins at their level positions, pins g and e at their lowermost and uppermost points of displacement respectively. This latter motion produces lateral abrasion between yarns. The diagram also shows the eccentric k at its maximum counterclockwise position. Fig. 5 shows the harness pins f and d at their bottom and top positions respectively. At this instant the reed starts its cycle of beat-up motion and returns before the harness pins begin to repeat their up and down cycle. For one up and down motion of the harness pins, the beat-up picks once. A pawl and ratchet action concomitantly releases the let-off roll b and engages the take-up roll h to draw the test warp through the abrader at the rate of one inch per forty-five picks. This action repeats itself at a speed of 150 cycles per minute of the beat-up.

CHAPTER III

PROCEDURE

The accomplishment of this paper required undertaking the following steps:

1. The evaluation of the abrasive and tensile forces determined by Kennedy (15).
2. The design and construction of an experimental abrader which would comply as closely as possible with the results evaluated from step one above.
3. The running of tests with the Zweigle Abrader, The Laboratory Abrader and the Scott Tester.

Evaluation of Existing Results.--The static tensions were taken as satisfactory, whereas, the dynamic tensions were considered fair since the method used to determine these values was such that the timing of the readings with the loom actions could have been off considerably. Moreover, the time lag which is due to inertia effects of the tension-meter could have been appreciable, yet was unaccounted for.

The frictional forces due to the lateral rubbing of the ends as the harnesses pass the level position, were considered unsatisfactory. The method employed in attempting to measure these forces was acceptable except that no provisions were made to account for timing effects of the different parts of the loom, on the strain readings. For example, how much if any of the strains determined on the harness straps were due to the take-up control pulling the warp forward? Only the harness inertia effects and the lateral rubbing effects of the warps were considered.

Since the experimental procedure and the techniques used in determining the kinetic frictional forces are basically sound and the experimental data obtained seemed quite uniform, the results of these forces were taken as satisfactory.

Design and Construction of the Laboratory Abrader.--The machine was to be designed and built so that it would rapidly and accurately make possible the determination of the effectiveness of a given size on a warp.

From the standpoint of accuracy, actions similar to those of a loom were designed into the machine in approximately the same types of motions and magnitudes which affect warp yarns (see Figs. 6 and 7, and Tables 1 and 2).

For rapidity of operation, a simplified technique of threading the machine to prepare it for testing was devised. To accomplish this, no heddles were provided for in the basic design of the machine. The frictional effect of the heddles is considered negligible (16).

The crossing of the ends at points e and 4,and g and 3 (Fig. 2), was done to permit rubbing of ends laterally.

Although this motion produces frictional forces which are of no specified magnitudes, it approaches the motion of a loom (see Figs. 6 and 7).

The machine was designed to run at a speed of 155 cycles per minute in order to agree with the weaving speed of a loom and thus to give equivalent stress and frictional characteristics.

By trial and error runs, the correct amounts and surface finishes were determined for all those surfaces which abrade the test samples. By using the principle of work and energy (see chapter four for theory), the frictional forces were determined. As an example, a known weight is attached to a string which is wrapped around a pulley whose frictional resistance is known. The free end of the string is passed over the surface of the element whose friction is to be determined. The weight is released and timed for a given interval of travel. With the recorded values of time, distance of drop of weight, and any known frictional values in the system, the unknown frictional resistances are obtained.

It has been shown by many investigators that in a weaving loom, the portion of the path of travel of a warp which is the most potential source of trouble is that between the drop-wires and the fell of the cloth. It is there that a traversing warp is subjected to high stresses and frictional forces by virtue of the loom characteristics.

For this reason, the design of The Laboratory Abrader incorporates only this portion of loom action from a standard weaving loom.

Experimental Procedure.--General: The testing with the Zweigle Abrader and The Experimental Abrader was performed in an uncontrolled atmosphere as there was no space with conditioned air readily available. Moreover, tests have been carried out in ambients where the humidity varied considerably and there has been no evidence to indicate its effect on the number of warp breakages (17). The average of the temperatures and the relative humidities which were recorded during the testing periods are, temperature 74°F and relative humidity 65 percent (see Table 7, appendix).

Test samples used: Three batches of cotton warp yarns, each sized with a different formula were employed. The description of each of the three yarn samples is listed as follows:

Yarns A (light size)

Size formula	96 lbs. starch 14 lbs. fatty compounds
Yarn counts	22's(for all three samples)

Yarns B (medium size)

Size formula	125 lbs. starch 15 lbs. fatty compounds

Yarns C (heavy size)

Size formula	146 lbs. starch 18 lbs. fatty compounds

Use of The Laboratory Abrader: A full length specimen from a given batch was placed on the abrader in accordance with the prescribed technique (see chapter two), until six test samples were on the machine. The shed was then closed by rotating one of the gears by hand and an initial tension of 3.70 grams per end imposed on the six yarns by means of a hanging weight which is well clamped to the ends. The machine was then started and the dynamic tensions for the opened and closed shed positions were checked on the tension-meter. Abrasion was continued until all the ends had broken. The number of harness action cycles (equivalent to the crankshaft cycles of a weaving loom) required to break each of the six samples, was recorded. This procedure was repeated until three complete samples of 300 yarns each were tested.

Use of the K. Zweigle Abrader: Twenty test ends of Yarn A (about eighteen inches long) were loaded on the machine in preparation for testing. Refer to chapter two for the threading technique. The motor was then started and the yarns were abraded until all the ends had broken. The number of cycles necessary to break each end was recorded. This was done until 1200 ends were tested from each of the three yarn samples available. This testing was carried out at a speed of 80 cycles per minute for each run.

Care was taken to thread each run in such a way that alternate notches on the guide bar and at the clamp were used. These notches serve as guides to prevent placing a yarn sample over an abrading surface which has been previously utilized. By using a different notch for each end per run, as much as five runs can be made without using up the entire abrading surface.

From the start, it was noticed that the ratchet and pawl which engages the abrading cylinder were not functioning properly. Instead of rotating the cylinder one twentieth of a revolution per abrasion cycle, there were times when no rotation took place. All runs during which this fault occurred were earmarked for investigation for possible inconsistencies. Sufficient excessive inconsistencies were found on all such runs that after careful scrutiny, the results for only 620 ends of Yarn A, 880 ends of Yarn B, and 740 ends of Yarn C were retained for statistical evaluation.

With the data from both the Zweigle Abrader and The Laboratory Abrader, the standard deviations from the means and the cumulative frequencies were calculated.

The Scott Tester: With this machine the stress-strain diagrams were made for fifteen specimens of each yarn sample. From these diagrams the tensile strengths and the percent elongations were determined for each.

Table 1. Static and Dynamic Tensions

(Refer to Figs. 6 and 7)

Machine	Shed Position	Static Tensions Measured Between Locations A & B (grams per end)	Dynamic Tensions Measured Between Locations A & B (grams per end)
Weaving Loom	Open	10.10	13.96
	Closed	3.70	1.09
Laboratory Abrader	Open	10.21	13.72
	Closed	3.72	1.26

Table 2. Kinetic Frictional Forces Per End

(Refer to Figs. 6 and 7)

Machine	Frictional Forces in grams at Different Positions			
	A B	C	D	E
Weaving Loom (Open Shed)	0.40	0.39	5.82*	Unknown
Laboratory Abrader (Open Shed)	0.38	0.32**	5.90*	5.90 (Assumed)

* This is an average value obtained by adding the friction for the heddle-up position to the friction for the heddle-down position.

** This is the total friction which is due to pins C and C'.

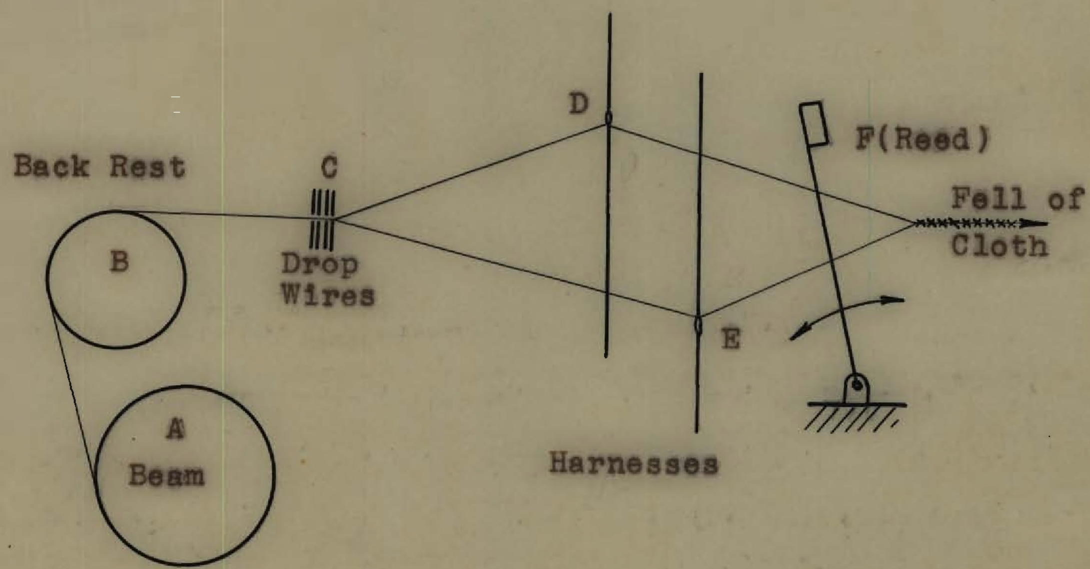

Fig. 6. Cross-section of Actual Loom

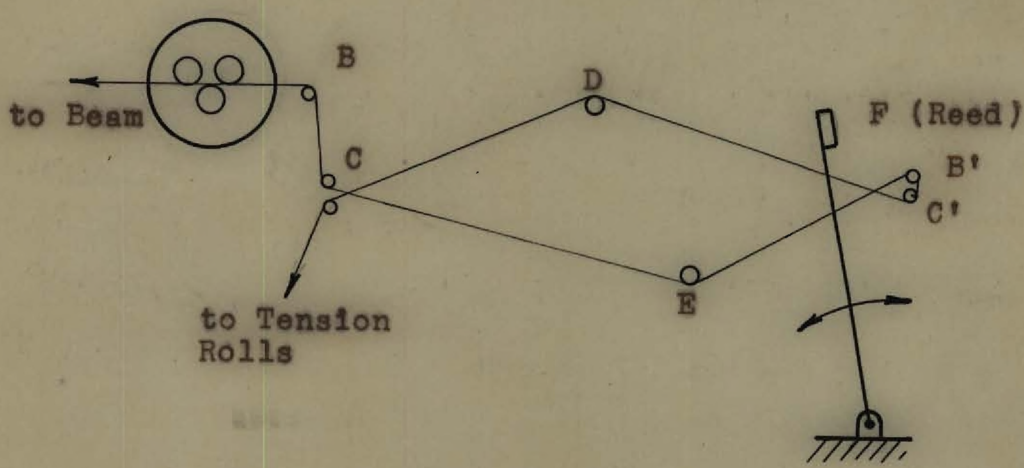

Fig. 7. Cross-section of the Laboratory Abrader

CHAPTER IV

THEORY, RESULTS AND ANALYSIS

Theory for Determining Friction Properties

The fundamental concept of work and energy was employed to obtain the frictional values of all the pieces investigated. Basically, a weight is tied to a string, wound around a free-rolling pulley and passed over the element whoxe friction is to be determined (see Fig. 8). The weight (w) is allowed to drop at a constant acceleration for a given height (x) and the time (t) required to traverse this distance, is recorded. The potential energy lost by the system (PE_w) during the interval that the weight dropped, is equated to the total kinetic energy imparted to the system ($KE_w + KE_p$, etc.) plus the total frictional energy overcome in the system ($T_p + T_m$, etc.).

<u>Test One</u>.--The determination of the kinetic friction of the free-rolling pulley (T_p). For tests one through four, refer to Figs. 7 and 8.

$$PE_w = KE_w + KE_p + T_p$$

$$wx = \frac{wv^2}{2g} + \frac{I\Omega^2}{2} + T_p \tag{1}$$

Test Two.--The determination of the kinetic friction of the specimen M (T_m). M is the pin at position C.

$$PE_w = KE_w + KE_p + T_p + T_m$$

$$wx = \frac{wv^2}{2g} + \frac{I\Omega^2}{2} + T_p + T_m \qquad (2)$$

Test Three.--This test is performed in the same manner as test two. M, here, refers to the pins of positions B' and C'.

Test Four.--Again this test is performed in the same manner as test two. In this case, however, M refers to the harness pins of positions D and E.

For the above four tests, the following terms are defined:

KE = kinetic energy

PE = potential energy

T = frictional moment

v = linear velocity

I = mass moment of inertia

g = acceleration of gravity

Ω = angular velocity

In equations (1) and (2), such terms as v and Ω are unknown but can be replaced by known quantities by making use of the following considerations:

For constant acceleration, $x = v_{ave.}(t)$

$$\text{i.e.,}\quad x = \frac{v_f + v_1}{2}(t) \tag{3}$$

but in these frictional tests, $v_1 = 0$,

$$\text{therefore,}\quad x = \frac{v_f}{2}(t)$$

$$\text{or,}\quad v_f = \frac{2x}{t} \tag{4}$$

Also, from the basic equation $v = r\Omega$,

$$\Omega = \frac{v}{r} = \frac{2x}{rt} \tag{5}$$

Equations four and five show that $\underline{v}$ and $\underline{\Omega}$ have been converted in such a way as to be ultimately expressed in terms of the known quantities: the distance which the weight drops (x), the time interval for this displacement (t), and the radius of the pulley (r).

Statistical Methods Theory

The mean $\bar{x}$ and the standard deviation σ were the only statistical values determined, where:

$$\bar{x} = \frac{k}{N}\sum_{i=1}^{N} f_i x_i + x_z \tag{6}$$

$$\sigma = k\left[\frac{\sum_{i=1}^{N} f_i (x_i)^2}{N}\right]^{\frac{1}{2}} \tag{7}$$

The terms in the above equations are defined as follows:

k = the number of specimens in one of the grouped frequency intervals

X_z = the midpoint of the interval of greatest frequency

f_i = the frequency of interval $\underline{i}$, where $\underline{i}$ is an integer such that $1 \leq i \leq N$

N = the total number of given frequencies of each set of grouped data

X = the distance of the midpoint of a given class interval from the midpoint of the interval of greatest frequency, as an integer $\underline{j}$, where $0 \leq j \leq 0$ (this term is used in tables 15 through 20)

Sample calculations for equations six and seven may be found at the bottom of table 15 (see appendix).

Results

Table 3 summarizes the results of all the tests carried out with each piece of equipment used.

The constituents of the formulas used on each sample yarn vary slightly in proportion except for the amounts of starch (see experimental procedure in chapter three). Yarn A has light weight size, Yarn B has medium weight size, and Yarn C has heavy weight size.

From a brief look at tables 3 and 4, it can be seen that such properties as percent elongation and tensile strength are very little affected by change in weight of size, whereas, the effect is quite pronounced on the abrasion resistance of the yarns.

The Zweigle Abrader results show a significantly different percentage difference (see table 4) when compared with the results of The Laboratory Abrader. This might be attributed to the fact that during the first twenty cycles of abrasion with the Zweigle Abrader, a fresh (previously untouched) surface of abrasive paper is acting on the yarns. Thereafter, the abrasion effectiveness of the paper decreases perceptibly for every twenty cycles, by virtue of the fact that the abrading cylinder rotates one twentieth of a turn about its own axis for every cycle through which it oscillates.

The Laboratory Abrader, however, imparts a constant abrasive action on the yarn surfaces until the ends begin to break. This happens because the number of yarns that impose lateral abrasion on each other decreases. The change is very insignificant, nevertheless, since the lateral abrasion magnitudes are small to begin with.

Table 3 shows that the percent of standard deviation from the mean, varies between 9.2 percent and 15.4 percent for the abrasion tests made with The Laboratory Abrader, while, the Zweigle Abrader results indicate a variation between 38.6 percent and 51.4 percent. In other words, the dispersion of points is widespread on either side of the mean for the Zweigle Abrader data, whereas, the distribution is narrow or considerably more regular for the values which The Laboratory Abrader yielded. This variance is also detectable from Figs. 9 and 10. The flatter curves indicate a wider dispersion of points than those curves which are sharp.

From the same table it is seen that Yarn A and Yarn C resist abrasion the least and the most, respectively, as results of the abrasion testing with both machines.

From the few tests which were made to determine the percent elongation and the tensile strength, and from the many abrasion resistance tests performed, a reasonable conjecture is that such static tests as percent elongation and tensile strength do not yield results which are a reliable index of weaveability. Since the property of abrasion resistance appears very sensitive to sizing changes, it could conceivably be utilized to accurately investigate sizing effects on the weaveability of warp yarns.

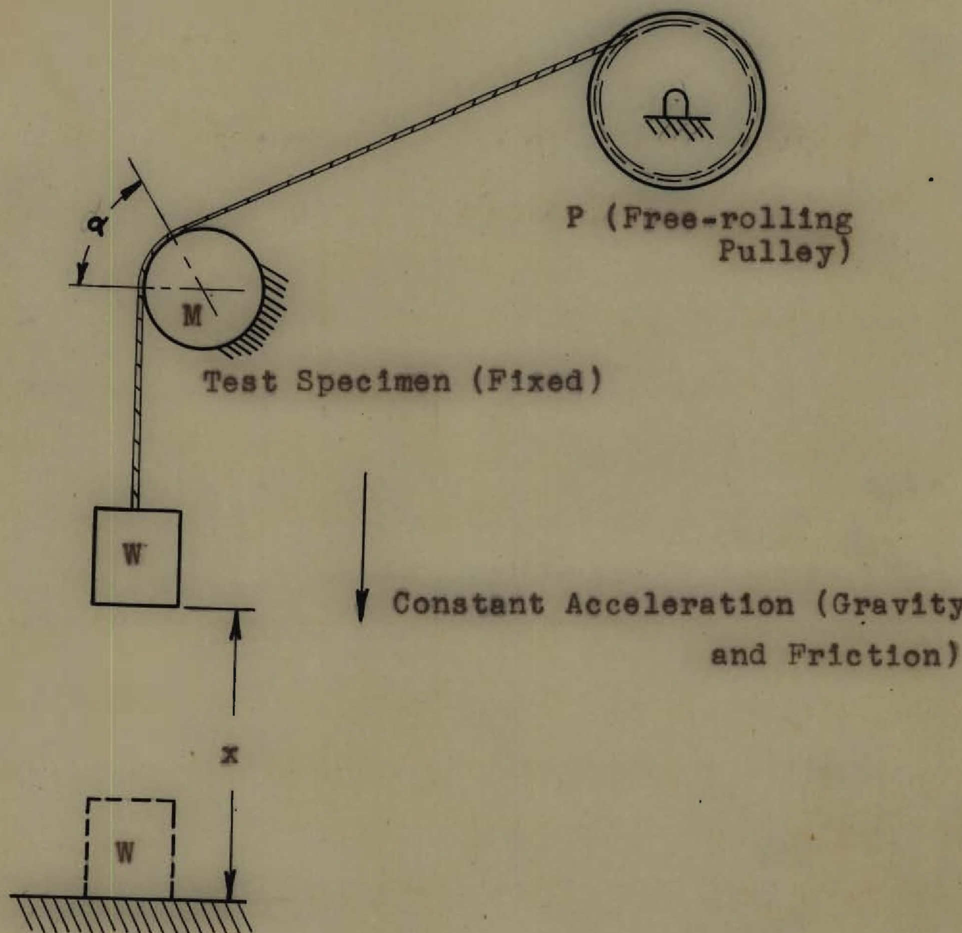

Fig. 8. Friction Tests Set-Up

Table 3. Test Results

	Yarn A		Yarn B		Yarn C	
	Z.A.	L.A.	Z.A.	L.A.	Z.A.	L.A.
Mean Number of Abrasion Cycles for Breakage	107	554	163	651	205	762
Standard Deviation in Cycles	55	75	65	60	79	117
Percent Standard Deviation from the Mean	51.4	13.5	39.9	9.2	38.6	15.4
Average Percent Elongation	4.9		4.8		4.6	
Average Tensile Strength in grams	360		340		345	

Note: Z.A. stands for Zweigle Abrader
L.A. Stands for Laboratory Abrader

Table 4. Resume of the Effect of Percent Size on the Properties of Yarn

		Effect of % Size in Terms of % Difference *	
		Difference Between Yarns A and B in %	Difference Between Yarns B and C in %
Resistance to Abrasion in Cycles	Lab. Abrader	17.5**	17.0
	Zweigle Abrader	52.0	21.0
Percent Elongation		2.0	2.4
Tensile Strength		5.7	1.5

* This means the difference between similar properties derived from two differently sized yarns, in percentage.

** Sample calculation for the resistance to abrasion difference:

$$\frac{651-554}{554} \times 100 = 17.5\ \%$$

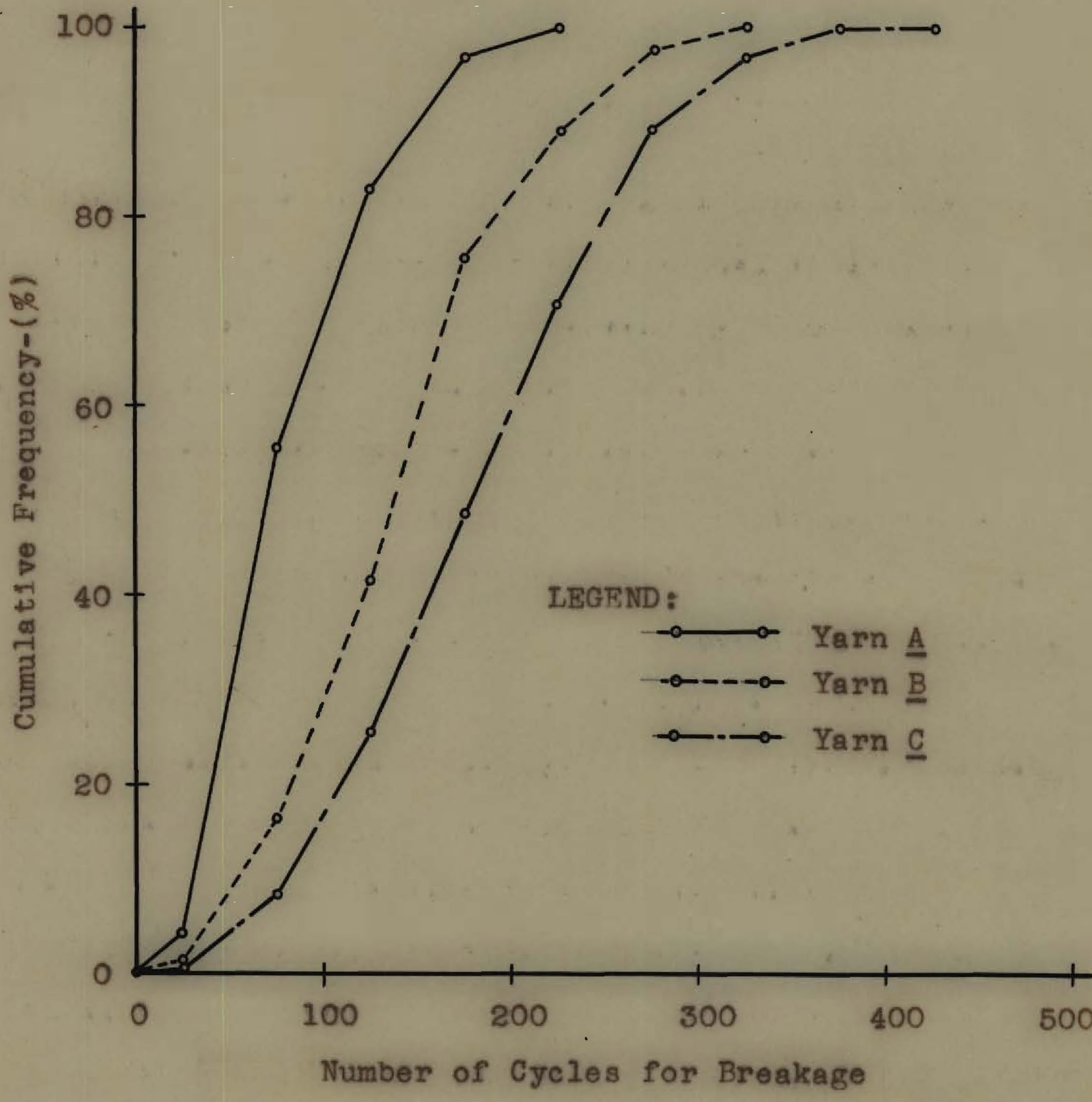

Fig. 9. Cumulative Frequencies Plotted Against Number of Cycles of Breakage for Zweigle (K.) Abrader

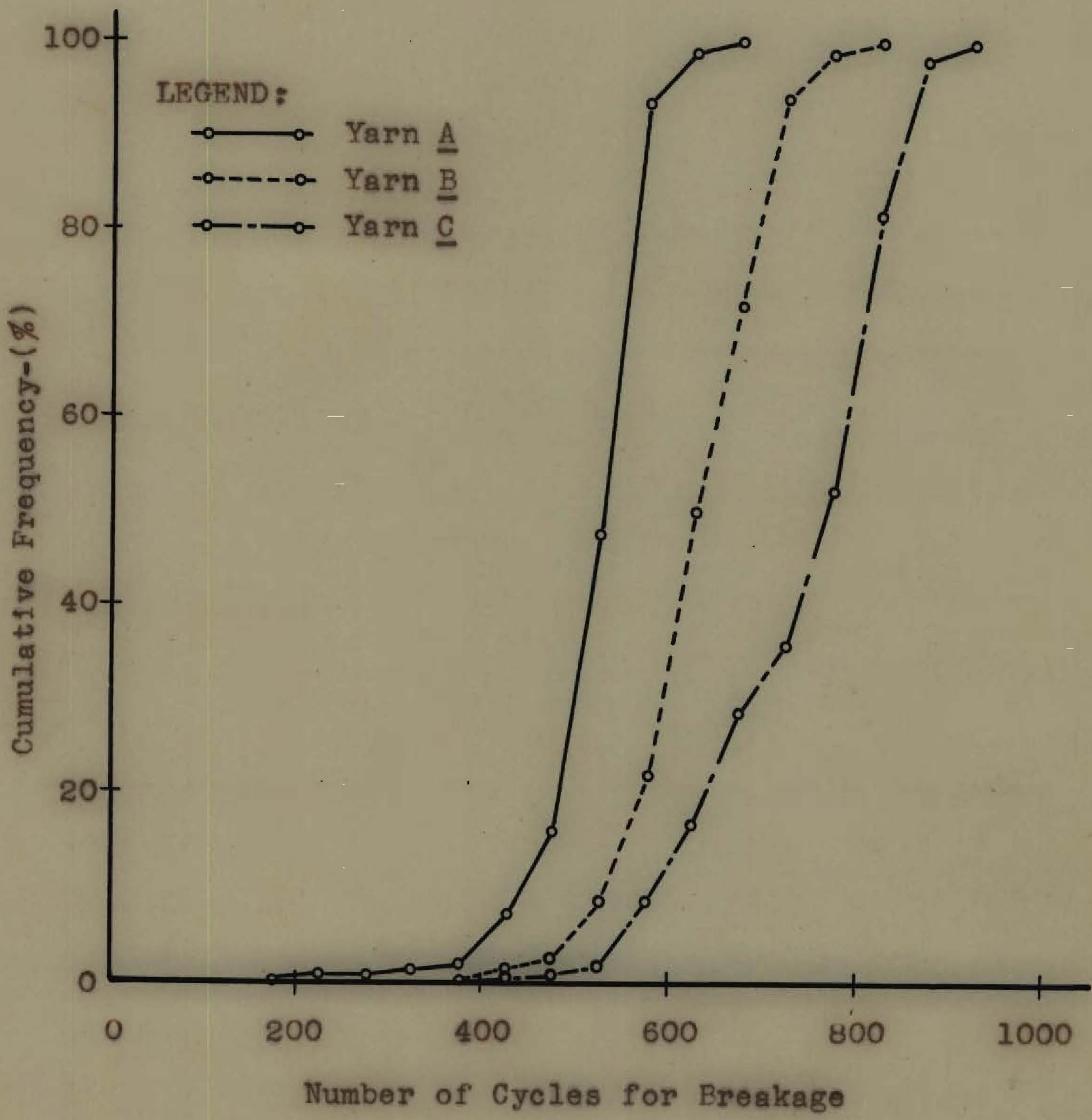

Fig. 10. Cumulative Frequency Plotted Against Number of Cycles of Breakage for Laboratory Abrader

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Conclusions.--The value of a testing machine which would emulate sufficiently the process of actual abrasion and stress fluctuations imposed by a weaving loom on a warp, is fully appreciated in textile circles.

The experimental results herein arrived at, indicate that tests on such static properties as percent elongation and tensile strength are insufficiently sensitive to sizing changes, to be employed in assessing the weaving qualities of a sized warp. The resistance to abrasion results, however, appear very sensitive to sizing changes and, consequently, could be used as sufficient criteria for arriving at an adequate index of weaveability. Similar results have been obtained by Kenk (19) and other investigators.

The Laboratory Abrader has the following characteristics:

(a) From the standpoint of exactitude, it imposes on a yarn, very nearly the same magnitudes of abrasive and tensile actions as a weaving loom does since these features have been quantitatively designed into it.

(b) As far as rapidity of tests are concerned, no appreciable amount of time saving has been accomplished on the machine since it is still in its experimental stages. With a few small changes, however, as many as fifty ends can be tested in it in approximately the same period of time required to test six ends per trial.

(c) The machine is essentially an abrader although strain variations are also imposed on the yarn being tested.

The test results from The Laboratory Abrader are very consistant with those from the K. Zweigle Abrader.

If a combined stress-abrasion test is to be a reliable guide, it must closely resemble the actions which a specimen would normally undergo in actuality.

It is evident from the foregoing, that such an abrader as The Laboratory Abrader could be fully developed to become a valuable adjunct to textile testing equipment.

Recommendations.--It is suggested that a machine of this character be considered for improvement from the standpoint of diminishing the overall time required for one testing trial, in the following ways:

(a) Improve the threading technique.

(b) Make necessary small changes to increase the number of ends to be tested per run.

(c) Increase the speed of the abrasion cycle and determine speed factors to account for the added speed effect.

The possibility of incorporating ways to measure the amounts of shedding should be examined since this quantitative value has been determined to be very significant in evaluating warp sizes.

A P P E N D I X

Table 5. Atmospheric Conditions for Testing Periods

Date	Temperature in °F			% Relative Humidity		
	High	Low	Mean	High	Low	Mean
April 15	81	65	73	73	58	66
16	84	68	76	67	43	55
17	86	61	74	71	51	61
18	82	66	74	72	50	61
19	84	65	75	70	52	61
20	80	71	76	72	60	66
21	72	63	68	89	56	73
22	80	61	71	79	51	66
23	82	67	75	83	55	69
Average of the Mean			74			65

Table 6. % Elongation of Samples

Trial	Yarn A	Yarn B	Yarn C
1	4.8	4.2	5.1
2	4.2	3.9	4.3
3	4.4	4.5	4.5
4	4.1	4.1	4.0
5	5.6	5.8	4.0
6	3.9	4.6	5.1
7	5.3	5.3	5.0
8	6.1	5.2	4.8
9	5.9	5.1	5.6
10	5.2	5.3	5.4
11	5.9	4.9	4.0
12	5.4	4.9	3.7
13	5.1	5.7	4.9
14	4.3	3.8	4.0
15	4.7	5.2	4.1
Average	4.9	4.8	4.6

Table 7. Tensile Strength of Yarn Samples in Grams

Trial	Yarn A	Yarn B	Yarn B
1	414	363	404
2	351	315	386
3	367	379	342
4	299	291	326
5	399	370	350
6	387	362	349
7	385	350	385
8	340	391	312
9	412	303	341
10	378	311	311
11	329	332	323
12	292	337	341
13	361	300	350
14	340	344	318
15	337	362	338
Average	360	340	345

Table 8. Kinetic Frictional Data for Laboratory Abrader

Run	Test No. 1		Test No. 2		Test No. 3		Test No. 4	
	h in Inches	t in secs.	h in Inches	t in secs.	h in Inches	t in secs.	h in Inches	t in secs.
1	50	5.8	38	3.6	55	9.5	29	3.4
2	50	6.1	38	4.2	55	9.9	29	2.7
3	50	6.5	38	3.6	55	10.3	29	2.7
4	50	6.1	38	3.7	55	9.9	29	3.3
5	50	6.7	38	3.6	55	10.6	29	2.7
6	50	6.0	38	4.3	55	9.8	29	2.8
7	50	6.0	38	3.7	55	9.8	29	2.8
8	50	6.5	38	4.1	55	10.5	29	3.2
9	50	6.0	38	3.7	55	9.8	29	2.8
10	50	6.1	38	3.5	55	10.0	29	2.9
Ave.	50	6.2	38	3.8	55	10.0	29	2.9

Table 9. Resistance to Abrasion in Laboratory Abrader for Yarn A (in cycles)

Trial									
1	2	3	4	5	6	7	8	9	10
302	519	518	418	542	495	522	520	460	500
451	522	524	471	543	512	551	533	499	517
471	537	559	489	571	552	578	549	520	515
506	550	579	521	600	569	588	556	538	579
525	572	620	635	651	600	602	582	562	610
601	620	720	642	652	610	613	602	570	631
11	12	13	14	15	16	17	18	19	20
418	470	469	422	502	465	450	499	500	427
487	521	499	497	535	512	479	525	539	948
501	541	539	500	561	539	499	560	579	520
520	572	572	531	581	555	540	580	599	550
582	650	619	590	597	596	569	599	650	580
630	655	621	625	621	612	582	600	652	599
21	22	23	24	25	26	27	28	29	30
430	460	467	429	412	523	530	427	512	501
510	521	547	500	491	560	561	446	542	538
540	531	590	537	502	588	565	502	569	570
556	561	600	551	509	591	572	531	582	580
622	587	650	601	527	625	600	598	583	603
635	630	655	621	590	626	627	602	600	619
31	32	33	34	35	36	37	38	39	40
520	531	457	499	520	520	213	492	467	427
562	562	492	521	487	545	532	519	527	499
586	653	503	536	503	561	545	521	539	507
601	578	522	540	513	590	582	530	572	519
621	590	530	601	582	672	632	585	600	567
630	622	550	639	621	687	672	622	621	630
41	42	43	44	45	46	47	48	49	50
495	419	437	519	462	427	400	502	490	511
488	455	467	530	479	462	442	513	521	512
499	491	481	536	496	500	501	529	547	570
501	509	521	542	553	521	510	552	549	582
531	539	590	641	559	601	518	589	552	632
562	550	600	641	679	640	592	689	603	720

Table 10. Resistance to Abrasion in Laboratory Abrader for Yarn B (in cycles)

Trial									
1	2	3	4	5	6	7	8	9	10
507	607	633	611	619	500	640	631	519	577
520	608	674	632	675	521	680	662	527	597
539	617	700	642	678	539	702	685	560	618
590	638	709	661	699	582	735	703	605	662
600	652	762	701	717	601	737	717	630	702
651	699	827	730	739	566	790	730	670	739
11	12	13	14	15	16	17	18	19	20
519	567	561	521	530	597	578	619	601	607
530	583	582	532	539	630	602	605	630	625
541	602	592	550	600	690	625	650	653	602
602	657	627	569	635	707	657	678	692	645
617	682	635	679	685	760	667	702	705	675
678	765	702	719	711	801	725	723	727	716
21	22	23	24	25	26	27	28	29	30
611	499	639	597	593	577	620	597	619	608
632	542	672	637	595	670	650	626	635	627
666	600	691	700	965	672	703	672	635	650
702	662	709	722	651	682	704	701	659	662
709	685	709	730	671	699	709	725	640	669
789	725	717	772	755	725	727	726	725	718
31	32	33	34	35	36	37	38	39	40
401	575	590	561	639	603	579	520	518	637
509	590	592	595	635	621	592	562	592	658
533	600	612	603	676	650	603	695	605	693
602	700	668	667	683	655	629	698	621	708
617	720	705	705	685	665	639	719	659	721
689	780	721	717	761	695	680	729	650	762
41	42	43	44	45	46	47	48	49	50
601	599	546	621	643	619	592	412	579	640
642	632	592	639	670	630	621	590	602	682
659	639	620	667	701	653	630	595	635	700
700	650	671	701	725	702	672	609	682	718
751	655	681	720	751	718	685	625	682	737
765	700	770	765	752	727	729	695	709	739

Table 11. Resistance to Abrasion in Laboratory Abrader for Yarn C (in cycles)

Trial									
1	2	3	4	5	6	7	8	9	10
412	612	569	572	709	650	583	561	627	552
650	629	656	655	789	701	695	671	659	600
762	690	736	790	790	702	812	750	705	655
812	762	754	841	790	807	861	813	785	764
861	808	785	865	857	817	865	861	831	795
870	812	787	879	861	864	936	872	835	801
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
602	582	600	540	555	707	621	570	691	595
691	589	592	650	616	715	720	659	729	675
735	685	800	699	680	800	830	761	820	800
751	828	842	790	733	851	835	801	865	836
800	861	867	821	778	881	836	811	895	855
802	865	901	830	790	887	850	835	899	860
21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
625	595	601	601	555	601	581	702	601	617
655	667	642	671	686	717	690	719	695	682
735	782	698	712	751	782	727	798	850	791
793	860	802	761	820	826	787	835	862	837
861	880	829	785	838	833	807	917	895	841
896	880	861	785	839	832	808	920	903	878
31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
578	701	613	565	551	580	549	617	659	592
685	755	685	639	698	702	629	711	699	679
762	765	721	698	729	761	701	781	757	800
812	769	758	785	761	780	790	785	860	812
815	870	791	819	801	822	815	791	898	813
872	881	795	828	829	830	817	813	901	815
41	**42**	**43**							
553	619	411							
602	625	599							
699	680	621							
779	785	695							
812	816	761							
821	830	792							

Table 12. Resistance to Abrasion in Zweigle Abrader for Yarn A (in cycles)

Trial									
1	2	3	4	5	6	7	8	9	10
73	45	41	63	44	66	50	29	23	45
74	52	65	64	101	67	70	46	30	55
75	52	67	65	110	70	71	55	38	70
76	55	69	79	115	75	72	62	46	70
88	60	70	80	122	76	75	63	64	74
87	70	72	85	126	75	77	65	73	80
91	80	97	90	127	84	80	72	74	86
100	81	99	100	128	94	82	73	75	90
109	92	100	109	130	96	85	76	79	99
116	96	111	121	138	97	88	79	80	100
126	100	118	122	139	114	90	81	84	100
129	105	130	133	141	122	95	82	88	106
131	111	139	140	176	126	105	85	91	107
145	116	140	157	187	133	115	90	95	109
147	141	150	158	183	139	125	92	113	110
155	143	155	160	186	145	135	95	114	113
156	152	160	164	199	149	140	99	115	123
198	160	169	210	199	165	145	100	139	131
200	170	188	211	210	168	151	109	157	145
230	200	185	214	211	191	182	139	170	205
11	12	13	14	15	16	17	18	19	20
39	55	36	53	55	53	74	44	46	58
50	56	45	56	51	57	75	45	60	60
52	72	55	57	59	69	77	50	70	63
55	73	57	70	67	70	80	55	71	75
60	75	62	76	69	71	91	57	73	77
93	76	66	77	75	80	92	74	84	82
97	77	77	78	77	81	95	76	99	88
98	78	79	85	79	92	96	83	100	106
114	100	84	86	82	93	113	87	102	108
118	101	85	87	85	96	114	92	119	111
125	102	87	89	86	111	127	99	123	117
137	107	89	95	89	115	128	103	139	128
137	115	90	97	90	118	135	109	144	136
141	117	95	100	92	123	136	111	147	143
169	118	105	105	93	126	150	138	153	154
174	119	110	107	94	129	152	134	159	155
184	135	116	109	95	139	159	147	162	158
195	136	117	111	112	162	156	159	167	167
200	140	125	133	115	181	204	165	189	209
201	199	140	180	130	185	209	166	194	213

Table 12. Continued

Trial									
21	22	23	24	25	26	27	28	29	30
44	54	35	58	60	48	79	24	18	71
53	67	38	59	62	67	80	29	57	77
56	70	53	61	63	73	81	51	62	78
61	71	53	67	68	73	87	57	69	81
63	72	59	79	71	74	94	60	71	85
87	73	67	79	76	81	95	63	74	89
99	74	73	80	79	83	96	69	76	92
113	81	79	81	81	90	107	70	83	97
115	96	79	88	83	95	113	74	87	99
119	97	81	90	87	97	123	79	87	100
125	98	86	90	91	116	132	79	88	102
136	111	87	97	94	120	139	80	94	119
142	114	88	102	94	122	139	80	97	122
167	115	100	107	95	126	141	86	100	130
173	116	102	109	96	129	153	90	102	131
178	129	109	111	96	134	159	97	109	134
187	132	112	127	97	145	162	100	112	135
189	137	119	129	109	169	168	101	137	159
202	141	141	135	117	189	205	137	142	160
208	148	146	149	182	197	223	142	153	176

Table 13. Resistance to Abrasion in Zweigle Abrader for Yarn B (in cycles)

Trial									
1	2	3	4	5	6	7	8	9	10
42	57	77	88	100	51	58	73	59	96
56	94	83	92	133	52	75	79	67	123
57	95	133	137	140	57	144	84	69	131
68	107	149	143	157	58	149	131	77	132
100	109	152	148	158	90	154	137	86	137
106	118	153	149	162	97	155	146	104	139
114	134	162	161	163	108	179	159	129	147
115	139	163	163	167	110	180	167	140	156
122	140	168	166	180	117	187	192	153	169
128	142	169	167	181	119	190	199	157	178
135	143	172	170	183	147	191	228	159	193
170	157	173	178	187	161	201	228	163	206
177	160	184	186	190	156	245	270	167	216
187	171	185	187	195	169	246	273	182	223
194	174	245	191	196	177	257	279	183	250
203	225	269	219	213	205	263	286	200	251
258	229	273	268	235	218	279	301	209	248
274	240	283	273	264	222	293	323	211	251
290	247	297	298	268	276	304	324	227	289
296	253	300	302	271	300	327	339	233	289
11	12	13	14	15	16	17	18	19	20
58	50	76	78	101	64	90	106	81	46
60	67	77	82	104	71	95	123	82	53
83	74	115	102	105	86	100	126	89	109
86	77	120	113	111	89	102	137	89	114
85	78	121	114	114	91	113	143	94	117
92	93	122	121	115	118	114	156	109	119
103	96	146	126	125	132	120	166	129	147
104	104	148	129	141	142	122	167	133	149
113	112	179	136	150	145	131	189	137	158
116	122	195	145	162	148	139	192	142	162
127	137	210	149	171	155	146	193	149	171
146	138	222	152	180	168	151	197	155	189
150	164	252	222	181	203	152	206	167	190
180	168	282	237	192	215	163	211	168	221
189	172	305	241	210	227	169	213	173	223
193	190	306	246	243	236	182	230	175	227
214	203	317	248	245	249	188	236	187	261
223	224	322	271	275	275	253	298	247	290
256	237	323	283	287	260	254	299	248	291
261	240	331	304	301	263	255	300	251	293

Table 13. Continued

Trial									
21	22	23	24	25	26	27	28	29	30
102	79	56	111	75	42	60	101	59	20
113	80	57	113	78	57	67	137	60	60
124	106	87	130	78	59	98	141	67	67
127	109	89	137	79	103	112	148	74	84
127	112	94	147	87	113	113	155	76	92
130	113	99	149	90	113	126	163	79	103
131	123	109	158	99	116	139	171	83	107
136	127	112	159	108	147	140	179	89	121
138	141	114	167	111	152	142	182	99	126
143	143	117	170	112	159	151	186	121	138
146	150	120	170	113	162	152	187	130	139
147	156	121	176	120	163	156	190	138	142
149	163	122	181	136	167	164	193	143	150
152	167	122	189	152	184	165	197	149	153
152	168	151	192	164	193	170	199	158	162
157	168	167	197	167	201	172	233	159	165
163	169	180	199	187	210	230	240	166	167
170	173	189	207	190	239	231	248	169	198
171	182	191	210	213	265	233	251	199	200
176	262	196	270	236	287	240	262	223	219

Table 14. Resistance to Abrasion in Zweigle Abrader for Yarn C (in cycles)

Trial									
1	2	3	4	5	6	7	8	9	10
38	119	37	142	148	55	95	66	58	70
79	180	79	165	170	69	96	76	63	115
98	185	84	184	192	91	116	99	105	140
131	190	100	194	210	100	117	100	106	147
133	216	104	213	211	127	213	122	107	150
165	248	126	224	231	135	152	139	110	151
176	230	137	225	235	139	175	146	120	155
179	285	138	254	257	145	200	168	144	185
180	292	184	255	274	154	218	180	156	190
181	293	187	257	286	175	273	200	163	195
188	295	201	265	290	178	286	201	188	217
195	302	203	291	295	179	296	204	190	220
196	308	210	299	300	193	311	208	200	231
202	309	211	318	316	194	320	220	201	244
219	320	212	382	318	203	322	225	206	250
223	343	220	383	339	210	333	228	212	256
227	345	238	412	341	218	337	264	233	271
235	370	240	423	352	225	338	270	250	277
250	373	249	424	366	240	341	280	255	287
355	375	253	282	379	300	350	302	270	300
11	12	13	14	15	16	17	18	19	20
80	104	104	72	64	31	130	75	58	140
85	142	126	79	86	37	137	80	69	162
120	149	139	111	99	52	139	95	91	186
141	150	140	115	100	55	157	125	107	202
145	155	164	153	124	58	158	127	129	223
152	156	181	163	141	60	174	130	135	230
195	165	186	165	146	160	175	160	139	231
209	170	189	172	149	160	189	162	148	261
210	171	210	188	170	161	193	170	155	265
216	190	212	192	172	164	221	173	178	280
230	195	213	203	173	166	233	190	178	281
235	196	227	205	186	168	240	195	179	287
237	197	235	241	195	170	255	208	199	300
240	220	268	246	228	171	259	214	199	301
241	226	271	250	231	193	263	220	208	335
242	236	274	259	239	204	267	273	210	332
269	259	335	272	285	234	290	273	211	350
275	262	360	280	315	257	305	288	217	357
285	265	405	292	375	261	318	300	300	380
364	275	420	297	390	273	360	301	319	384

Table 14. Continued

Trial									
21	22	23	24	25	26	27	28	29	30
43	121	57	140	110	100	44	71	84	100
67	127	59	163	113	103	46	79	86	101
100	129	87	180	143	135	55	103	123	120
153	133	89	186	146	137	57	104	127	123
160	161	108	189	158	161	60	125	150	132
167	171	113	190	159	164	63	127	159	156
178	210	142	190	169	183	111	149	213	173
179	211	147	193	170	187	113	159	214	202
189	213	188	225	175	207	147	172	216	223
198	231	198	231	176	208	149	182	217	270
201	247	210	250	210	211	155	190	218	289
209	249	211	256	211	213	157	198	221	290
262	290	216	286	213	231	159	213	235	310
262	298	221	289	216	234	161	226	239	323
263	310	231	293	221	270	170	235	246	330
273	311	238	297	223	279	178	257	253	340
278	316	241	302	238	281	209	269	265	351
281	319	244	309	239	283	213	270	269	352
301	321	280	312	283	321	221	286	299	355
320	323	286	314	296	324	225	287	313	371

Table 15. Mean, Standard Deviation and Cumulative Frequency for Yarn A (Laboratory Abrader)

Class Interval	Midpoint (cycles)	Frequency of Interval f	X	fX	$f(X)^2$	Cumulative Frequency cycles	Cumulative Frequency %
0-50	25	0	0	0	0	0	0
51-100	75	0	0	0	0	0	0
101-150	125	0	0	0	0	0	0
151-200	175	0	0	0	0	0	0
201-250	225	1	-6	-6	36	1	0.33
251-300	275	0	-5	0	0	1	0.33
301-350	325	2	-4	-8	32	3	1.00
351-400	375	1	-3	-3	9	4	1.33
401-450	425	18	-2	-36	72	22	7.33
451-500	475	25	-1	-25	25	47	15.66
501-550	525	95	0	0	0	142	47.33
551-600	575	85	1	85	85	227	75.66
601-650	625	54	2	108	216	281	93.66
651-700	675	16	3	48	144	297	99.66
701-750	725	3	4	12	48	300	100.00
Total		300		175	667	1325	

Sample Calculations:

$$\text{(Mean) } x = \frac{50}{300}(175) + 525 = 554 \text{ cycles}$$

$$\text{(Standard Deviation) } \sigma = 50\sqrt{\frac{667}{300}} = 75 \text{ cycles}$$

Table 16. Mean, Standard Deviation and
Cumulative Frequency for Yarn B
(Laboratory Abrader)

Class Interval	Midpoint (cycles)	Frequency of Interval f	X	fX	f(X)2	Cumulative Frequency cycles	%
0-50	25	0	0	0	0	0	0
51-100	75	0	0	0	0	0	0
101-150	125	0	0	0	0	0	0
151-200	175	0	0	0	0	0	0
201-250	225	0	0	0	0	0	0
251-300	275	0	0	0	0	0	0
301-350	325	0	0	0	0	0	0
351-400	375	0	0	0	0	0	0
401-450	425	3	-4	-12	48	3	1.00
451-500	475	3	-3	- 9	27	6	2.00
501-550	525	21	-2	-42	84	27	9.00
551-600	575	38	-1	-38	38	65	21.66
601-650	625	84	0	0	0	149	49.66
651-700	675	68	1	68	68	217	72.33
701-750	725	64	2	128	256	281	93.66
751-800	775	16	3	48	144	297	99.00
801-850	825	3	4	12	48	300	100.00
Total		300		155	713	1345	

Table 17. Mean, Standard Deviation and Cumulative Frequency for Yarn C (Laboratory Abrader)

Class Interval	Midpoint (cycles)	Frequency of Interval f	X	fX	$f(X)^2$	Cumulative Frequency cycles	%
0-50	25	0	0	0	0	0	0
51-100	75	0	0	0	0	0	0
101-150	125	0	0	0	0	0	0
151-200	175	0	0	0	0	0	0
201-250	225	0	0	0	0	0	0
251-300	275	0	0	0	0	0	0
301-350	325	0	0	0	0	0	0
351-400	375	0	0	0	0	0	0
401-450	425	2	-8	-16	128	2	0.66
451-500	475	0	-7	0	0	2	0.66
501-550	525	2	-6	-12	72	4	1.33
551-600	575	22	-5	-110	550	26	8.66
601-650	625	24	-4	-96	384	50	16.66
651-700	675	35	-3	-105	315	85	28.33
701-750	725	21	-2	-42	84	106	35.33
751-800	775	56	-1	-56	56	162	54.00
801-850	825	82	0	0	0	244	81.33
851-900	875	51	1	51	51	295	98.33
901-950	925	5	2	10	20	300	100.00
Total		300		-382	1635	1576	

Table 18. Mean, Standard Deviation and Cumulative Frequency for Yarn A (K. Zweigle Abrader)

Class Interval	Midpoint (cycles)	Frequency of Interval f	X	fX	$f(X)^2$	Cumulative Frequency cycles	Cumulative Frequency %
0-50	25	26	-1	-26	26	26	4.33
51-100	75	306	0	0	0	332	55.33
101-150	125	165	1	165	165	497	82.99
151-200	175	84	2	168	336	581	96.99
201-250	225	19	3	57	171	600	100.00
Total		600		384	718	2036	

Table 19. Mean, Standard Deviation and Cumulative Frequency for Yarn B (K. Zweigle Abrader)

Class Interval	Midpoint (cycles)	Frequency of Interval f	X	fX	$f(X)^2$	Cumulative Frequency cycles	Cumulative Frequency %
0-50	25	5	-3	- 15	45	5	0.83
51-100	75	92	-2	-184	368	97	16.16
101-150	125	176	-1	-176	176	273	41.50
151-200	175	181	0	0	0	454	75.60
201-250	225	80	1	80	80	534	89.00
251-300	275	52	2	104	208	586	97.66
301-350	325	14	3	42	126	600	100.00
Total		600		-149	1003	2549	

Table 20. Mean, Standard Deviation and Cumulative Frequency for Yarn C (K. Zweigle Abrader)

Class Interval	Midpoint (cycles)	Frequency of Interval f	X	fX	$f(X)^2$	Cumulative Frequency	
						cycles	%
0-50	25	4	-3	- 12	36	4	0.66
51-100	75	51	-2	-102	204	55	9.16
101-150	125	99	-1	- 99	99	154	25.67
151-200	175	136	0	0	0	290	48.67
201-250	225	133	1	133	133	423	70.93
251-300	275	104	2	208	416	527	88.12
301-350	325	52	3	156	468	579	96.93
351-400	375	20	4	80	320	599	99.93
401-450	425	1	5	5	25	600	100.00
Total		600		361	1501	3239	

B I B L I O G R A P H Y

A. LITERATURE CITED

1. Castle & Dawson, "Some Factors Affecting Warp Breakages," Textile Institute Journal, 40, 1949, p. 331-2.

2. Brown, B. J., "The Nature and Incidence of Warp Breakages in Automatic Weaving," Textile Institute Journal, 40, 1949, p. 307.

3. Ibid., p. 301.

4. Castle & Dawson, op. cit., p. 338.

5. An Old Timer Says, "A Loom for Testing Single Ends of Yarn," Cotton, 106, September 1942, p. 101.

6. Bradbury, E., "Testing of Sizes for Continuous Filament Yarns of High Strength," Textile Institute Journal, 46, 1949, p. T299.

7. Collier, "Testing for Evaluating Shedding of Warp Yarns," Bulletin of Southern Research Institute, Nos. 1-7-8-12, 1948.

8. Worth, D. L., "Test for Sized Yarn," Textile Industries, 116, June 1952, p. 92-5.

9. Hicks, E. M. & Scroggie, A. G., "Taber Yarn-Sheet Abrasion Tester," Textile Research Journal, 18, 1949, p. 416.

10. Goldthwait, "Abrasion Tester for Sized Yarn," Textile Monthly, 76, 1929, p. 2805-8.

11. An Old Timer Says, op. cit., p. 101.

12. Worth, D. L. & Stallings, J. W., "Modified Abrasion Test for Warp Sizing Study," Textile Industries, 114, March 1950, p. 94-5.

13. Kenk, "Abrasion Resistance As a Measure of Sizing Effect on Warps," Textil Praxis, 1952, p. 698-702.

14. Kennedy, C. W., A Study of Loom Actions Affecting Warp Yarns, Unpublished Masters Thesis, Georgia Institute of Technology, 1953.

15. Ibid., p. 52-64.

16. An Old Timer Says, op. cit., p. 102.

17. Brown, <u>op. cit.</u>, p. 312.

18. Kenk, <u>op. cit.</u>, p. 701-2.

B. OTHER REFERENCES

1. Abrams, "Warp Shed Tester Evaluates Slasher Size," <u>Textile World</u>, 102, February 1952, p. 132-3.

2. ASTM Committee D-13, <u>ASTM Standards on Textile Materials</u>, Philadelphia, American Society of Testing Materials, 1951, p. 333.

3. Anon, "Sizing and Weaving Research," <u>Textile Mercury and Argus</u>, 122, May 12, 1950, p. 771, 773-5.

4. Anon, "Two Ways to Test Warp Size," <u>Textile World</u>, 100, March 1950, p. 124-7.

5. Baines, J. & Steiger, J. V., "Some Caused Effects of Warp Breaks," <u>Textile Institute Journal</u>, 40, 1949, p. 299-300.

6. Bradbury, E., "Effect of Sizing on Warp Breakage," <u>Textile Institute Journal</u>, 40, 1949, p. 272.

7. Bradbury, E. & Hacking, H., "Experimental Technique for Mill Investigation of Sizing & Weaveability," <u>Textile Institute Journal</u>, 40, 1949, p. 532.

8. Craxton, C. E. & Cowden, D. J., <u>Statistical Methods</u>, p. 80.

9. Dyer, Faw & Beard, "Some of the Factors Affecting Yarn Tension in Warping," <u>Textile Research Journal</u>, 22, July 1952.

10. Evans, T. F., "Evaluation of Warp Sizing," Technical Report, Textile Research (Institute of Princeton), 8, 1950, p. 134.

11. King, D. E. & Weil, H. A., "Evaluation of Textile Sizes," <u>Textile Research Journal</u>, 22, 1952, p. 567-73.

12. Taylor, "Distinguished Factors in Weaveability," <u>Textile Institute Journal</u>, 40, 1949, p. 353-62.